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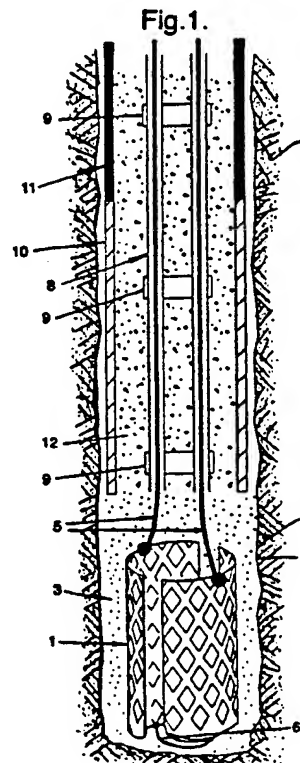
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(54) **Electrical heater**

(57) A heater is disclosed which comprises an electrical insulating material surrounding an annular heating element configuration; wherein there is no casing surrounding an annular heating element configuration.



**EP 0 940 558 A1**

## Description

### FIELD OF THE INVENTION

[0001] This invention relates to a electrical heating method and apparatus useful in a borehole.

### BACKGROUND TO THE INVENTION

[0002] U.S. Patent Nos. 4,640,352 and 4,886,118 disclose conductive heating of subterranean formations of low permeability that contain oil to recover oil therefrom. Low permeability formations include diatomites, lipid coals, and oil shales. Formations of low permeability are not amiable to secondary oil recovery methods such as steam, carbon dioxide, or fire flooding. Flooding materials tend to Penetrate formations that have low permeabilities preferentially through fractures. The injected materials bypass most of the formation hydrocarbons. In contrast, conductive heating does not require fluid transport into the formation. Oil within the formation is therefore not bypassed as in a flooding process. Heat injection wells are utilized to provide the heat for such processes.

[0003] Heat injection wells can also be useful in decontamination of soils. U.S. patents 5,318,116 and 5,244,310, for example, disclose methods for decontamination of soils wherein heat is injected below the surface of the soil in order to vaporize the contaminants. The heaters of patent '310 utilize electrical resistance of spikes, with electricity passing through the spikes to the earth. Patent '116 discloses heater elements passing through the wellbore to the bottom of the formation to be heated. The wellbore surrounding the heater includes a catalyst bed, which is heated by the heater elements. Heat conductively passes through the catalyst bed to a casing surrounding the catalyst bed, and then radiantly from the casing to the soil surrounding the wellbore. Typical alumina based catalysts have very low thermal conductivities, and a significant temperature gradient will exist through the catalyst bed. This significant temperature gradient will result in decreased heat transfer to the earth being heated at a limited heater element temperature.

[0004] U.S. patent no. 5,065,818 discloses a heater well with sheathed and mineral insulated ("MI") heater cables cemented directly into the wellbore. The MI cables includes a heating element surrounded by, for example, magnesium oxide insulation and a relatively thin sheathing around the insulation. The outside diameter of the heater cable is typically less than one half of an inch (1.25 cm). The heater well optionally includes a channel for lowering a thermocouple through the cemented wellbore for logging a temperature profile of the heater well. Being cemented directly into the wellbore, a need for a casing (other than the sheathing of the cable) is eliminated, but the outside diameter of the cable is relatively small. The small diameter of the

heater cable limits the amount of heat that can be transferred to the formation from the heater cable because the area through which heat must pass at the surface of the cable is limited. A cement will have a relatively low thermal conductivity, and therefore, a greater heat flux at the surface of the cable would result in an unacceptably high heater cable temperature. Multiple heater cables may be cemented into the wellbore to increase the heat transfer to the formation above that which would be possible with only one cable, but it would be desirable to further increase the heat that can be transferred into earth surrounding the heaters.

[0005] U.S. patent 2,732,195 discloses an electrical heater well wherein an "electrically resistant pulverulent" substance, preferably quartz sand or crushed quartz gravel, is placed both inside and outside of a casing of a wellbore heater, and around an electrical heating element inside of the casing. The quartz is placed there to reinforce the casing against external pressures, and a casing that is sealed against the formation is required. The casing adds considerable expense to the installation.

[0006] It is therefore an object of the present invention to provide a wellbore heater wherein the heater has a greater surface area at the temperature of the electrical resistance element than those of the prior art, and in which a substantial casing is not required. This heater is useful as a well heater for such purposes as thermal recovery of hydrocarbons and soil remediation.

### SUMMARY OF THE INVENTION

[0007] These and other objects are accomplished by an electrical heater comprising an electrical insulating material surrounding an annular heating element configuration, wherein there is no casing surrounding the heating element configuration.

[0008] The casingless design of the present heater significantly reduces the cost of a heat injection well, which is significant in an application such as heat injectors for recovery of hydrocarbons from, for example, oil shales, tar sands, or diatomites. Heat injection can also be used to remove many contaminants.

[0009] It is preferred that the annular heating element configuration is selected from the group consisting of an annular porous metal sheet, one or more expanded metal plates, a wire mesh, and strips wires, rods or filaments connected by spacers.

[0010] In accordance with another aspect of the invention there is provided a method to heat a portion of the earth, the method comprising the steps of:

- providing a borehole within the portion of the earth to be heated;
- placing an annular heating element configuration within the borehole; and
- supporting the heating element configuration within the borehole with electrically insulating material,

wherein a metal casing is not provided between the heating element configuration and the earth to be heated.

## BRIEF DESCRIPTION OF THE DRAWINGS

[0011]

FIG. 1 shows first embodiment of a heater according to the present invention within a wellbore.

FIGS. 2A, 2B, and 2C show details of an electrical cable attached to the top of a heater according to the present invention.

FIG. 3 shows an alternative embodiment of a heater according to the present invention within a wellbore.

FIG. 4 shows a cross sectional view of the heater of FIG. 3 in a borehole.

FIG. 5 shows an apparatus for installing the heater of the present invention.

## DETAILED DESCRIPTION OF THE INVENTION

[0012] Optionally the annular heater of the present invention has a mesh heating element which can be formed to conform to a wall of a wellbore to maximize the surface of the heating element which is provided and to maximize the heat flux leaving the wellbore. An electrically insulating filler is placed around and inside of the heating element to essentially eliminate electrical shorting of the element to the formation. This electrically insulating material could be a material that is initially wet, and therefore electrically conducting until it is dried. The drying step could be accomplished by passing electricity through the heating element and into the wet material, and heat generated by the electrical energy would gradually heat the soil and eventually vaporize liquid water initially present. The remaining dry sand is an acceptable electrical insulator. Optionally, a hydraulic cement could be used in place of the sand. Hydration of the cement reduces free liquid water, and the cured cement can be an acceptable electrical insulator. Other materials could be used as the insulating material. Preferred materials are easily placed and inexpensive. An ideal material would also either be or readily become an electrically nonconducting material. A material such as sand could be placed pneumatically or as a slurry.

[0013] A plurality of electrical heating elements are preferably placed in the wellbore to form the heater, with the elements connected at the lower portion of the wellbore, and different phases of alternating electrical power applied to each of the elements. Two or three elements are preferred.

[0014] The heating elements can be expanded metal, or another porous metal element such as a wire screen or wire mesh. A porosity of between about forty percent and about eighty percent is preferred, where porosity is defined as the percent of open area looking at the sur-

face of the sheet of material. Providing this open area considerably increases the total area contacted by the element, without reducing the thickness of the element. A thicker element provided greater allowances for corrosion. Thickness of the element is chosen to result in a voltage requirement at the targeted heat flux which is not excessively low or high. For example, a voltage differential of about 120 to about 960 volts of alternating current between the upper ends of two elements within a wellbore which have connected lower ends would be preferred. Generally, for longer lengths of meter (100 to 700 meters) from 480 to 960 volts is preferred and for shorter meters (2 to 200 meters) from 120 to 480 volts is preferred. To accommodate greater thicknesses of elements, multiple heaters could be provided in series, but the extent to which this can be done is limited by the expense of the cables leading to the heater elements. Power is preferably applied between two symmetrical heater elements wherein the net voltage is zero. Thus the voltage applied at one time to one electrode is the negative with respect to ground of the voltage applied to the other heater element.

[0015] The elements are preferably formed into a curved shape either at the surface or within the borehole to conform to the walls of the wellbore. The curved shape could be provided at the surface by a die through which the metal is passed as it is passed into the wellbore. The curved shape could be provided within the wellbore by a passing a mandril past the element. The mandril could, for example, be provided as a part of an apparatus which spreads the elements and places the electrical insulating material around and between the elements. When the elements are formed into a curved shape at the surface, centralizers and spacers can be added to the elements to keep the elements separated within the wellbore. Use of the mandrel as described above is preferred because centralizers and spacers can be eliminated, reducing the cost of materials. Flat mesh-elements could be provided. The advantage of providing curved elements is that heat could be transferred from almost the entire circumference of the borehole, with two flat elements, heat could be transferred from a surface area of only about twice the diameter of the wellbore, but installation of the flat elements could be simplified compared to the semicircular shaped elements.

[0016] Generally, heater elements of stainless steel of, for example, grades 304 or 316 are preferred. INCOLOY 600 could also be useful (INCOLOY is a trademark). 316 stainless steel is preferred when the elements will be exposed to brines because of the greater resistance of 316 stainless steel to chloride stress corrosion. Stainless steels are not excessively expensive, and would withstand exposure to elements that may be present during start-up phases for long enough to get the elements up to elevated temperatures, and sufficiently low corrosion rates when exposed to most borehole environments for extend periods of time at elevated temper-

atures. Typically, stainless steels are not utilized as heater elements because of limited high temperature corrosion resistance, but because of the relatively large surface area from which heat is transferred in the heater of the present invention, the elements surface temperature can be suitable for stainless steels. Carbon steels could also be used as heater elements for applications where high levels of heat do not have to be provided for extended periods of time.

[0017] Although in a preferred embodiment of the present invention includes the use of stainless steel as the heater element material, higher alloys could be useful in some applications of the present invention. For example, when the heater is applied in a relatively deep wellbore, the costs of providing the well could be much greater than the costs of the heater element material, and therefore a higher alloy could reduce total costs by permitting operation at higher temperatures and thus reducing the number of wells required for the same total heat duty.

[0018] Alternatively, the heating elements could be coated with a more corrosion restive metal surface, or a refractor surface to provide additional electrical insulation and protection.

[0019] Thermocouples for control of the heaters could be provided within the wellbore, either inside of curved heater elements, outside of the elements, or attached to the heater elements (through an electrically insulating connection). The thermocouple could be used to monitor the operation, or to control electrical power applied to the heater element. When thermocouples are used to control the electrical power, multiple thermocouples could be provided and the a control temperature selected from the thermocouples. The selection could be based on a maximum temperature, an average temperature, or a combination such as an average of the highest two or three temperatures.

[0020] The heat elements of the present invention can be made to a wide variety of lengths because of the flexibility to select different combinations of voltages and porosities of the heater elements. Heaters as short as two to six meters can be used, and as long as two hundred to seven hundred meters could be provided.

[0021] A borehole within which the heater of the present invention is placed may be cased and cemented for at least a portion of the borehole above the heater, to ensure isolation of the formation to be heated. In a shallow well, the borehole may be filled with sand to the surface.

[0022] Referring now to FIG. 1, a schematic drawing of the annular heater of the present invention is shown. A mesh heater element 1 is shown as two semicircular expanded metal plates within a wellbore 2. An electrically insulating filler 3 such as sand is shown surrounding and between the heating elements. The borehole is within a portion of the earth to be heated 4, such as a formation of oil containing diatomite, tar sands or oil shale. Alternatively, the earth to be heated 4 could be

contaminated soil in a thermal desorption remediation process. Electrical leads 5 extend to each of the heater elements and the heater elements are electrically connected at the lower portion of the elements by connector 6. Alternatively, the elements could all be grounded at the base of the borehole. Electrical leads extend through the portion of the overburden which is not to be heated 7 through sheathed cables 8, the sheathed cables separated by spacers 9. A transition portion of the wellbore will be heated by the heater elements, but not to the temperatures that result in the portion of the borehole which contains the heater elements. This transition portion of the borehole is shown as cased by a casing 10, which may be of a metal such as stainless steel, which will have an acceptably long useful life when exposed to elevated temperatures. The corrosion environment within this transition volume may be more severe than the corrosion environment near the heaters because of the dew point temperature being within this region. Above the transition zone, the casing could be a carbon steel casing 11. The casing within the transition zone and the overburden 7 could be filled with a filler 12 such as sand or cement, or left void.

[0023] Referring now to FIG. 2A, 2B, and 2C, three views with partial cutaways are shown of fittings for electrical cables and connections to the heater element of the present invention. The top of the heater element 21 is connected to a high temperature lead cable 22 by a weld connection 33. A waterproof interface between the cable and heater A is within a transition zone. Above the transition zone, an inexpensive cable such as a polyethylene coated copper wire could be used. An electrically insulated high temperature section B extends from the waterproof interface to the heater element. A stiffener 24 provides support for the electrical connection to the heater element. The stiffener is attached to the cable by a collar 25. The collar is an electrically insulating collar. The water proof interface includes a coupling 26 around a soldered connection 27, the soldered connection providing continuity between the high temperature lead cable 22 and a low temperature lead cable 28. The coupling is threaded to swedge fittings 30, which may be brass fittings, and which provide a friction fitting to each of the high temperature lead sheath 31 and the low temperature lead sheath 23. Cable 23 goes from the surface to just above the top of the heater and can be a copper core-copper sheathed mineral insulated cable. This type of cable is preferred because of its ability to carry very large amounts of electrical power, and because it is waterproof. Although the cable can withstand high temperatures, it is used at temperatures below the boiling point of water due to corrosion rates. A waterproof splice (A) terminates the mineral insulated cable 23 and forms a transition to a nickel or nichrome clad-nickel electrode 22 that is welded 33 to the upper part of the heater 21. The nickel hot electrode 22 can be insulated with a TEFLON sleeve 31 to prevent corrosion of the nickel electrode and provide a waterproof seal at

the lower end of the cable transition 30 (TEFLON is a trademark). Stiffening arm 24 provides support to the TEFLON sleeved nickel electrode 22 during installation of the heater into a wellbore. The waterproof splice A can be about two to twenty feet above the top of the heater element. The water proof splice is far enough away from the heater so that the water proof splice remains at a temperature below the boiling point of water. The TEFLON coated high temperature lead is, at one point, exposed to the boiling point of water, and is easily capable of handling this environment. The lower (hotter) portion of the high temperature lead sheath 31 will eventually melt away, leaving exposed high temperature lead. Providing the TEFLON coating to this point ensures that the TEFLON extends past the point where the temperature is at the boiling point of water.

[0024] The high temperature lead sheathing could be any coating which would protect the high temperature lead from corrosion at temperatures of the boiling point of water or less, and would either withstand higher temperatures or melt away and not cause any corrosion at higher temperatures. Heat resistant resins are preferred because they provide a greater length of protected high temperature lead which could be helpful if the point at which the temperature is the boiling point of water moves. Acceptable high temperature resins include polyimide, polyamide-imide, and polyetheretherketone.

[0025] The high temperature lead sheath is separated from the high temperature lead by mineral insulation such as magnesium oxide. Copper leads are acceptable and effective for the low temperature leads, but nickel or nickel-chromium clad nickel are preferred for the high temperature leads.

[0026] Alternatively a plurality of elongate electrical heating elements are placed in the wellbore to form the heater, with the elements connected at the lower portion of the wellbore, and different phases of alternating electrical power applied the elements. At least six elements are preferred in order to provide heat around the entire circumference of the wellbore.

[0027] The heating elements can be, for example, stainless steel wire, nickel-chrome alloy wire or carbon fiber elements. The wires are preferably between about 0.2 and about 0.8 mm in diameter and more preferably about 0.3 mm in diameter. Thicker elements provided greater allowances for corrosion, but at the expense of greater current requirements and greater material costs. Thickness of the element is chosen to result in a voltage requirement at the targeted heat flux which is not excessively low or high. For example, a voltage differential of about 60 to about 960 volts AC between the upper ends of two elements within a wellbore which have connected lower ends would be preferred. For shorter heaters (2 to 200 meters), voltages of 60 to 480 volts AC are preferred, and for longer heaters (100 to 700 meters) a voltage of 480 to 960 volts AC is preferred. To accommodate greater thicknesses of elements, multiple heaters could be provided in series, but

the extent to which this can be done is limited by the expense of the cables leading to the heater elements.

[0028] Generally, heater elements of stainless steel of, for example, grades 304, 316, or 310 are preferred. Stainless steels are not excessively expensive, and would withstand exposure to elements that may be present during start-up phases for long enough to get the elements up to elevated temperatures, and sufficiently low corrosion rates when exposed to most borehole environments for extend periods of time at elevated temperatures. Carbon steels could be used as heater elements for applications where heat does not have to be provided for extended periods of time. For shallow applications such as soil remediation, nichrome 80 is preferred.

[0029] Thermocouples for control of the heaters could be provided within the wellbore, either inside of the ring of heater elements, outside of the elements, or attached to the heater elements. The thermocouples could be, for example, secured to one of the electrically insulating spacers. The thermocouple could be used to monitor the operation, or to control electrical power applied to the heater element. When thermocouples are used to control the electrical power, multiple thermocouples could be provided and the control temperature selected from the thermocouples. The selection could be based on a maximum temperature, an average temperature, or a combination such as an average of the highest two or three temperatures.

[0030] The heater elements of the present invention can be made to a wide variety of lengths because of the flexibility to select different combinations of voltages and diameters of the heater elements. Heaters as short as two meters can be used, and as long as 700 meters could be provided.

[0031] A borehole within which the heater of the present invention is placed may be cased and cemented for at least a portion of the borehole above the heater, to ensure isolation of the formation to be heated. In a shallow well, the borehole may be filled with sand or a bentonite slurry to the surface. The bentonite slurry prevents water ingress from above.

[0032] Referring now to FIG. 3, a schematic of the heater of the present invention is shown. Heater elements 101 (two shown) are provided with electrical leads to the elements 102 which are larger in diameter than the heater elements, but can be of the same material. The number of elements is preferably between two and six. The electrical leads are shown extending to individual heater elements, but a spacer could be provided wherein only one electrical lead is provided for each phase of electrical energy, and the power is applied in parallel or series to different heater elements. The borehole within which the heater is placed is preferably between about 5 and about 20 centimeters in diameter, and the heater element are preferably placed between about one half and about one centimeter from the wall of the borehole. The elements are preferably

separated by between about four and about eighteen centimeters. Fewer elements generally reduces the cost of the heater, but a larger number of elements permits greater heat flux into a formation from the heater at limited heater element temperature. The heater elements are not individually electrically insulated, but rely on the electrical insulating properties of electrically insulating filler material surrounding the elements. A casing 103 is provided at the surface for isolation, but preferably does not extend to the soil to be heated 104, but only through an overburden 106. Sand or a hydraulic or ceramic cement 105 is shown surrounding the heater elements. When the soil is to be heated to the surface, a short tube could be provided to provide a stable flange for securing the tops of the heater elements.

[0033] A flange 107 is shown with insulating sleeves 108 around the electrical leads to the heater elements. Power supply wires 109 provide electrical power to the electrical leads, and are secured by nuts 110.

[0034] An electrical insulating spacer 111 provides separation of the electrical elements within the borehole. One electrical insulating spacer is shown, but more than one can be provided, and preferably, one is provided each three to ten meters within the wellbore. Further, the electrical insulating spacer is shown within the heater section, but one or more can also be provided in the electrical lead-in section about the heaters. The electrical insulating spacers can be made from an inexpensive plastic, and do not necessarily have to withstand the elevated operating temperatures. The spacers only need to hold the heater elements in place while the filler material is placed around the elements. Alternatively the spacers could be made from ceramics such as alumina, or machineable ceramics such as MACOR (MACOR is a trademark).

[0035] The lower ends of the heater elements can be connected with an electrically conducting connector 112. The electrically conducting connector can connect all of the elements, or a combination of elements such that each of the elements has electrical continuity necessary for current to pass through the elements. The electrically conducting connector optionally has a cup 113 for securing the connector to a tube for lowering the elements, connector and spacer down the borehole. A tubing from, for example, a coiled tubing unit, could be placed within the cup 113, and the cup held to the coiled tubing either by, for example, a friction fit which could be broken by pressure from within the coiled tubing, or the tubing could be held to the cup by tension from the heater elements as the connector is lowered into the borehole.

[0036] The electrically conducting connector is shown at the bottom of the wellbore, with each heater element extending uniformly down the heated portion of the wellbore. But the number and/or heat duties of the heater elements can vary along the length of the heater. The diameters of the heating elements can vary along the length of the heater to tailor the heat deposition to a

desired profile.

[0037] Referring now to FIG. 4, a view looking down at the electrically insulating spacer is shown. Heater elements 101 (six shown) are separated by insulating spacer 111, with the electrically insulating filler such as sand or cement 105 surrounding the spacer and heater elements. The soil to be heated 104 surrounds the heater. The electrically insulating spacer 111 is shown as being in two parts, with mating tongues and grooves to allow the spacers to be slipped inside the heater elements and around a tube when the tube is being used to lower the heater elements into the borehole. A tie wrap 201 can be used to secure the heater elements in notches within the spacer. The spacer may be secured vertically to the heater elements by friction, or may be held vertically by clamps (not shown) placed above, or above and below the spacer on one or more of the heater elements.

[0038] Referring now to FIG. 5, an apparatus which can be used to place the heater of the present system into a wellbore is shown. Heater elements 101 (two shown) are strung over pulleys 301, the pulleys mounted on brackets 302 which are set on a flange 303. The flange 303 is mounted on the casing 103, which is equipped with a mating flange. The heater elements 101 are rolling off spools (not shown) and can be maintained in slight tension to prevent entanglement of the heater elements within the borehole. A coiled tubing 304 is shown extending into the borehole. The coiled tubing can be used to place the heater elements and electrical leads within the borehole, and then used to fill the borehole with the electrically insulating filler as it is removed.

[0039] The heating elements can be of a wide variety of lengths and a wide variety of distances down a borehole. For example, for heating an oil shale formation, the heater may be 400 meters long. For remediation of contaminated soil, the heater may be only two or three meters long, although longer heater elements are more advantageously provided by the present invention. The heaters may be provided an extended distance down the borehole. For example, an oil shale formation may be heated which lies under 400 meters of overburden. As the length of the heater and electrical leads become very long, the heater elements and/or electrical leads may be required to be of larger diameter or may need to be made of a material which has greater strength because these elements must be self supporting until the electrically insulating filler is placed around the elements. The heater elements therefore do not have to be self supporting at operating temperatures because friction with the electrically insulating filler will provide vertical support for the elements.

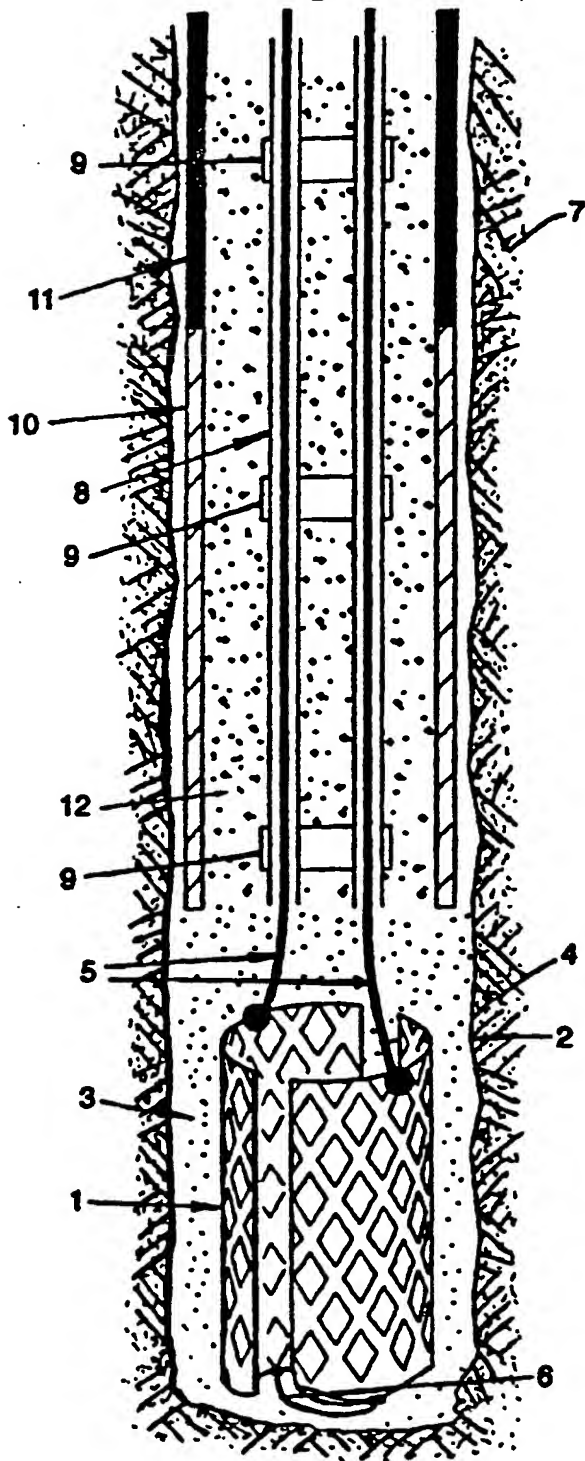
## 55 Claims

1. A wellbore heater comprising:

- an annular heating element configuration; and  
an electrical insulating material surrounding  
the annular heating element configuration;  
wherein there is no casing surrounding the  
annular heating element configuration. 5
2. The heater of claim 1 wherein the annular heating  
element configuration is selected from the group  
consisting of an annular porous metal sheet, one or  
more expanded metal plates, a wire mesh, and 10  
strips wires, rods or filaments connected by spac-  
ers.
3. The heater of claim 2 wherein the annular heating  
element configuration comprises at least one 15  
expanded sheet which is rounded to essentially  
comply with a portion of a wall of a wellbore.
4. The heater of claim 3 wherein a plurality of  
expanded slotted metal sheet heating elements are 20  
provided and each expanded slotted metal sheet is  
separated from the other expanded slotted metal  
sheets.
5. The heater of claim 4 wherein the plurality of 25  
expanded metal sheets are electrically connected  
at a lower extremity.
6. The heater of claim 5 further comprising a power  
supply to each of the expanded metal sheets at an 30  
upper extremity, and wherein each of the power  
supplies is a different phase of electrical power.
7. The heater of claim 1 wherein the electrical insulat-  
ing material comprises sand. 35
8. The heater of claim 1 wherein the electrical insulat-  
ing material comprises cement.
9. The heater of claim 1 wherein a plurality of 40  
expanded metal heating elements are provided and  
the plurality of heating elements are electrically  
connected to different phases of alternating electri-  
cal power at a powered end and electrically con-  
nected to a common ground at a ground end. 45
10. The heater of claim 2 wherein the heater comprises  
metal strips or rods which are separated by at least  
one electrically insulating spacer maintaining a  
separation between the elements and between the 50  
elements and the sides of the wellbore.
11. The heater of claim 10 further comprising an elec-  
trically conductive connector at the lower extremity  
of the metal strips or rods, the electrically conduc- 55  
tive connector providing electrical continuity  
between the strips or rods.
12. A method to heat a portion of the earth, the method  
comprising the steps of:  
  
providing a borehole within the portion of the  
earth to be heated;  
placing an annular heating element configura-  
tion within the borehole; and  
supporting the heating element configuration  
within the borehole with electrically insulating  
material, wherein a metal casing is not pro-  
vided between the heating element configura-  
tion and the earth to be heated.
13. The method of claim 12 further comprising the step  
of initiating electrical flow through the heating ele-  
ment configuration by passing electrical current  
from the heating element to the portion of the earth  
to be heated at a current effective to remove liquid  
water from the electrical insulating material; and  
increasing voltage applied to the heating element  
configuration as a resistance increases through the  
electrical heating element configuration.
14. The method of claim 12 wherein a plurality of heat-  
ing elements are provided; the heating elements  
are all electrically connected at a lower extremity of  
the heating elements; and different phases of elec-  
trical power are applied to the heating elements at  
an upper extremity of the heating elements.
15. The method of claim 14 wherein the heating ele-  
ments are selected from the group consisting of a  
stainless steel wire, nickel-chromium alloy wire, and  
carbon filament.



Fig.1.



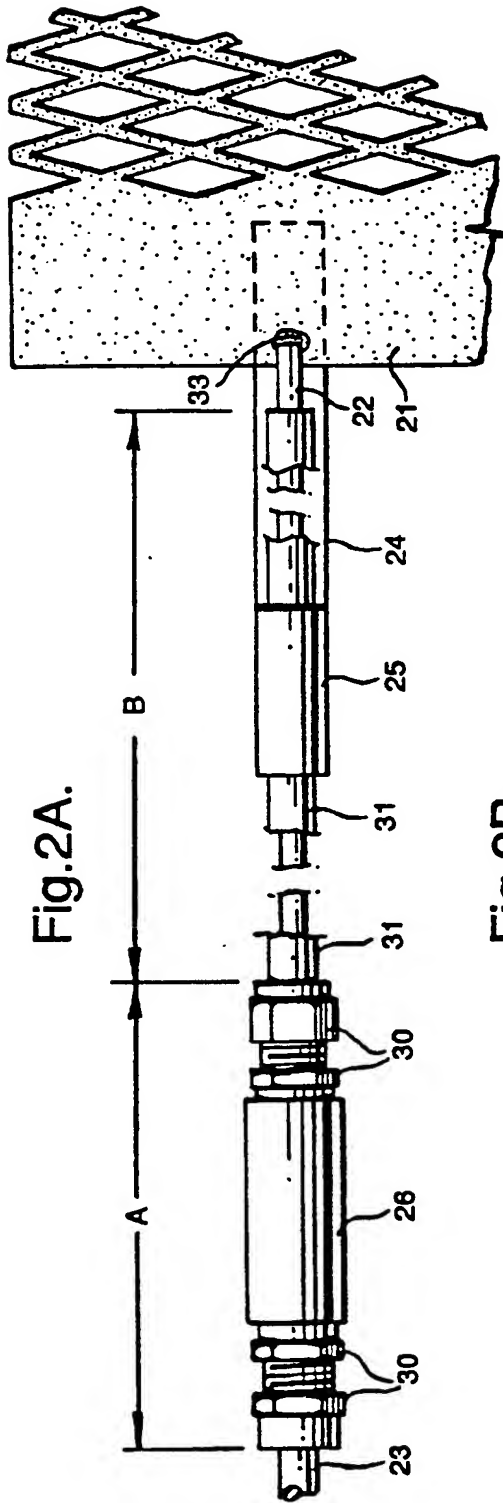


Fig. 2B.

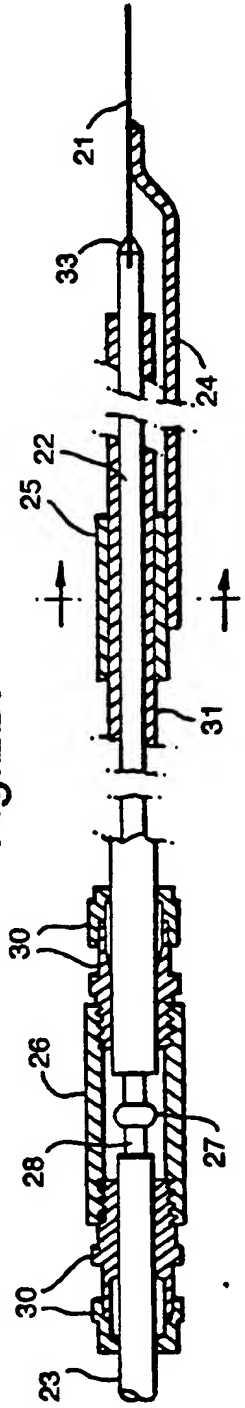
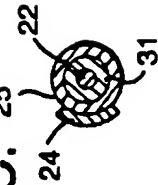
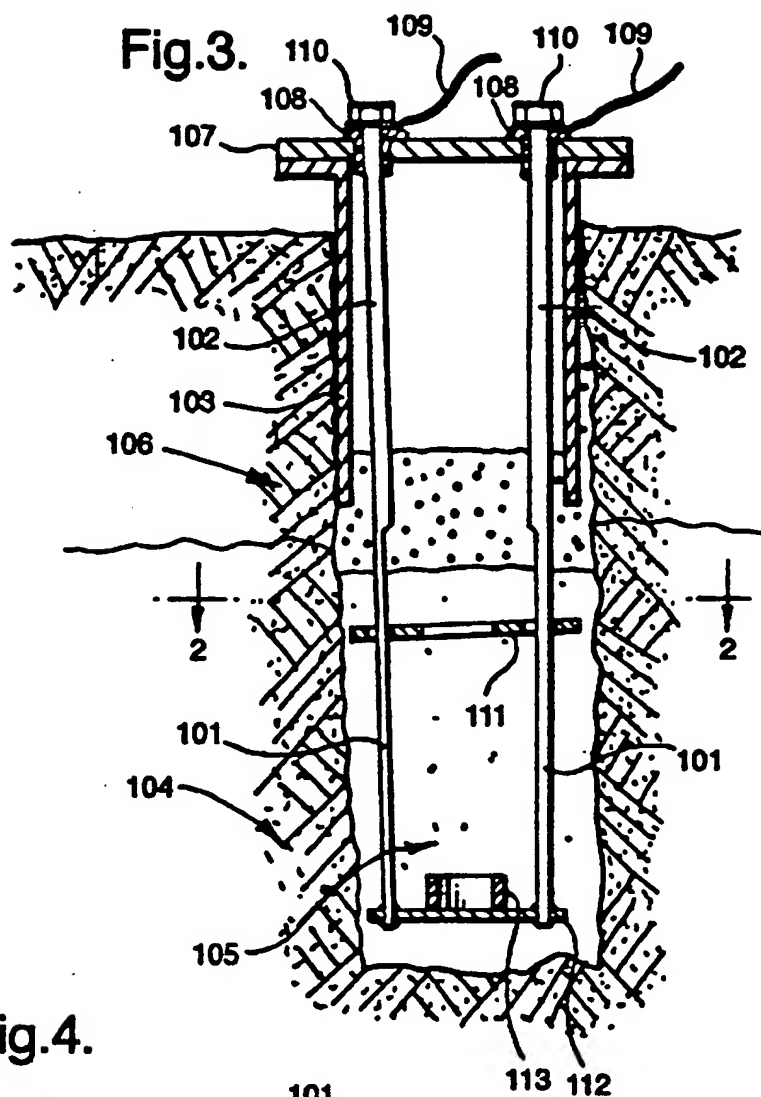


Fig. 2C.



**Fig.3.**



**Fig.4.**

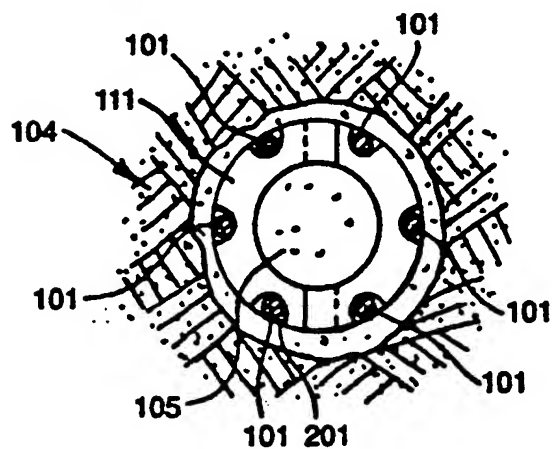
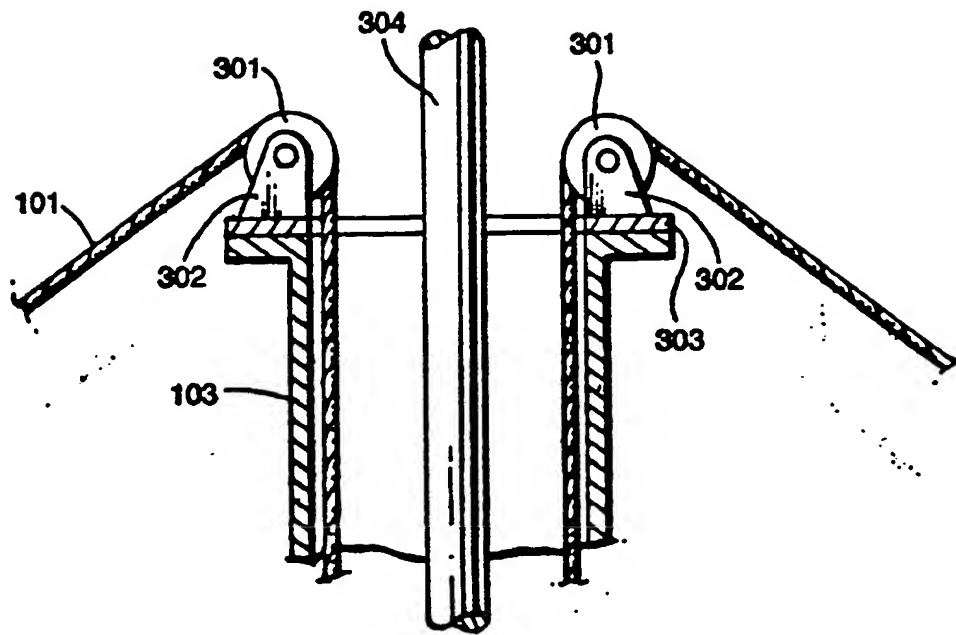


Fig.5.



European Patent  
Office

## EUROPEAN SEARCH REPORT

Application Number  
EP 99 20 0644

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	US 2 500 513 A (BOWMAN, H.) 14 March 1950 * column 1, line 52 - line 55 *	1	E21B36/04
Y	* figure 2 *	2,10,11	
Y	US 2 208 087 A (SOMERS, C.) 16 July 1940 * column 2, line 3 - line 15 * * figures 1,3 *	2,10,11	
Y,D	US 5 065 818 A (VAN EGMOND CORNELIS F H) 19 November 1991 * column 1, line 64 - column 2, line 25; figures 1,2 *	12	
Y	US 2 350 429 A (TROUPE) 6 June 1944 * page 2, left-hand column, line 3 - line 14 *	12	
A	* page 2, left-hand column, line 64 - line 71; figures 4,5 *	1,2	
A	US 2 362 680 A (TROUPE, D.) 14 November 1944	1,2	TECHNICAL FIELDS SEARCHED (Int.Cl.6)
			E21B B09C
The present search report has been drawn up for all claims			
Place of search MUNICH		Date of completion of the search 28 June 1999	Examiner Bellingaccl, F
CATEGORY OF CITED DOCUMENTS		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document			

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